Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia CIRP 7 (2013) 145 – 150

www.elsevier.com/locate/procedia

Forty Sixth CIRP Conference on Manufacturing Systems 2013

Design of Production Control´s Behavior

G. Schuh[a], T. Potente[a], C. Thomas[a,]*

[a] Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Steinbachstraße 19, Aachen 52074, Germany
* Corresponding author. Tel.: +49-241-8028381; fax: +49-241-8022293; *E-mail address*: c.thomas@wzl.rwth-aachen.de.

Abstract

Today, one of a company´s biggest challenge is to achieve a high adherence to delivery dates. The aim of production control is to ensure a robust production process despite of dynamic environmental influences in order to respond quickly to changes and to realize the achievement of logistic goals. Although many IT supporting tools have been developed in the past, employees of production control still have problems with intransparent control principles and run the risk to make wrong decisions. Especially socio-technical aspects are often neglected within the configuration process of production control. The aim of this paper is to introduce a new approach of the configuration of production control which includes socio-technical system effects.

Selection and peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha

Keywords: Production control; Socio-technical behaviour; Logistic targets

1. Introduction

Since the early 90´s, productions are characterized by short delivery times and products which are geared to fulfil individual customer requirements. In order to meet the demands of the market and to cope with increased international competition, life cycles in production have to be adapted to shorter cycles. At the same time, production volumes of single variants decrease while the number of variants rises. The drastic shortening of delivery times in recent years, for example in machine and plant construction by nearly 50%, has influenced the order fulfilment process and brought about the need for capacity flexibility of manufacturers [1]. The capability to adhere to delivery dates gains importance as it is perceived as a distinguishing feature and a decision criterion by customers [2].

The task of production control is to ensure a robust production process despite of dynamic environmental influences. The aim of production control is to respond quickly to changes and to realize the best possible achievement of logistic targets [3]. It is essential to control production processes in a way, logistic objectives such as delivery dates are met to their best as well as reduction of stock and costs. Thus, production control is a central lever to obtain a high adherence to logistic targets. It contributes significantly to a company's success by influencing the logistical performance. While the strategic importance of logistics and of meeting logistic objectives seems obvious, the realisation of a satisfactory standard is more of an issue [4].

2. MOTIVATION

The idea of this paper addresses the problems of production control configuration. The configuration of production control determines for example the way of releasing orders, of prioritizing orders and of planning capacities.

There is a lack of transparency and understanding of how control principles work. In many cases, employees of production control do not understand the logistic interdependencies and the control influences [1]. Furthermore, the variety of control principles has led to a selection problem which often results in false and irrational control decisions [5]. For employees it is neither obvious which impact sequencing roles have within an order fulfilment process nor can they anticipate the consequences of early order release. The reason for the employees' lack of understanding is for example job enrichment. While in past years for instance, employees were only responsible for producing parts on one machine, their scope of duties has expanded

Selection and peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha
doi:10.1016/j.procir.2013.05.025

by carrying out quality tests of the produced parts [6]. The consequence of broadening their latitude is the deterioration of understanding of a particular process. Furthermore, spatial distances between production control employees and machine operators may lead to misunderstandings. As a consequence, many irrational decisions are made in production and lead to a poor performance of production control. This fact is underlined by several projects in industry carried out by the Laboratory for Machine Tools and Production Engineering (WZL). For instance, the installation of a simple first-in-first-out production turned out to achieve better results as the suggestions made by IT tools using complicated algorithms [7].

In order to support employees' control decisions, several IT tools were developed during past decades. Supply Chain Management (SCM), Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) are some examples for those IT tools [8]. Nevertheless, many users are not satisfied with given IT solutions. The reason for this is that on the one hand necessary constraints such as the organizational structure and the necessity of a high data quality are neglected. On the other hand, the control logic within the systems is often intransparent to it's user. On a daily basis, new order priorities are calculated by the systems which users do not trust in. Therefore, employees on the shop floor rather set up their own production plans because they believe that with their interventions they can still save due dates of orders [9].

Further problems are inconsistent target systems between production and employees. While the production management insists on its main logistic target of good adherence to delivery dates, employees on the shop floor try to keep the capacity utilization of their machine high. Often, this effect is reinforced by utilization-related payment systems For instance, the introduction of a Kanban-system into a company's production failed because the employees' habits and the methods of payment contradicted to the Kanban idea [10].

Furthermore, organizational effects, such as the way employees work together and how they make their decisions, influence the performance of production control. Organizational forms, in which self-reliance and a sense of responsibility are supported, are the basis for proactive and failure-avoiding actions. Structures, in which employees can bring in their experience and knowledge, are an important basis for innovative ideas and the continuous improvement of internal processes [11]. In general, within the field of production control many decisions have to be made. For many of those decisions, employees of production control make use of external knowledge and have to communicate with other departments within their production system [12]. An industry project of WZL with a machine manufacturer showed, that the fulfilment of tasks like changing order plans, capacity plans, order release or material scheduling almost always asked for a decision.

3. STATE OF THE ART

In order to configure production control, Lödding structured the scope of duties within production control into four tasks. In the following, these four tasks as well as existing approaches for configuration of production control are explained.

3.1. Task of production control

The four tasks of production control consist of order generation, order release, sequencing and capacity control [13], see Fig. 1.

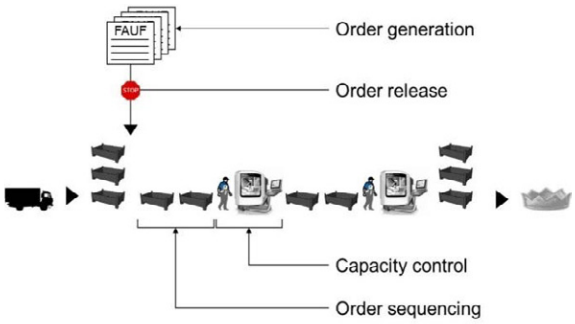

Fig. 1: Four tasks of production control

Order generation is the starting point of the order fulfilment process. Since the order generation determines for example the lot size, it has an influence on the work in process (WIP) level and the scattering of throughput times within production. Order generation principles are chosen on the basis of either customer order, forecasting or inventory level. The impact of order generation on WIP and throughput times is shown by an industry case of WZL: Halving the top 5% of biggest lot sizes resulted in a reduction of throughput times up to 20%.

The task of order release determines the production start of an order. Similar to order generation, order release influences WIP and hence capacity utilization and throughput times. Although many scientists like Goldratt, Spearman, Hopp, Lödding or Nyhuis underline the importance of limiting WIP, most IT systems are still not able to take this philosophy into account [4, 13, 14, 15].

The order sequencing determines the sequence in which orders waiting in front of a machine are processed. Thus, this production control task also influences logistic targets like throughput time and adherence to delivery date. Often, the sequencing is proposed by complex algorithms of IT tools. Simpler sequencing rules like first-in-first-out though can help to stabilise production and are often easier to understand for employees [7].

Capacity control is responsible for the proper occupancy of machines and allocation of employees. Thereby, capacity control influences the productivity and production costs. On the one hand, the aim of capacity control is to expand bottlenecks if needed; on the other hand, the separation of machine-operator-assignment enables more flexibility within production.

3.2. Existing approaches for configuration of production control

The topic of logistic targets interdependencies and the targeting of production control are discussed since the 1980s. The link between production inventory, production capacity and lead times of the orders was formulated in Little´s Law and in the funnel formula of Kettner and Bechte for the first time [16, 17]. The funnel formula implies that elements taking up capacity within the production can be described by material input, WIP and material output. By limiting WIP, throughput times can be controlled. Taking this insight into consideration, many principles for order release were developed.

In order to reduce differences between the production plan and real production output, H.-P. Wiendahl resorts to basic principles of controlling engineering. According to Wiendahl, the use of feedback enables a higher reaction rate to upcoming disturbances [18]. This approach is based on the comparison of plan- and as-is-values. Depending on the difference between these values, appropriate measures can be taken.

Nyhuis und H.-P. Wiendahl developed the Logistic Operating Curves to mathematically describe the correlations between the logistic targets [18]. With the help of these Logistic Operating Curves, the operating point of a production system can be determined. This is necessary for defining an appropriate level of WIP and simplifying the systematic determination of process parameters.

Further approaches for the configuration of production control are developed by Lödding and H.-H. Wiendahl. While Lödding´s approach is characterized by the structure of the four tasks of production control, H.-H. Wiendahl established a procedure to configure the production control. In this procedure, design and methodology aspects are determined before a set of methods is derived. The last step consists of the introduction of the order fulfilment process. With his scheme, H.-H. Wiendahl underlines the importance of socio-emotional aspects like the organizational structure. However, his approach rather relates these aspects to the introduction of order fulfilment process than to the previous configuration of production control.

According to Lödding´s approach, Schuh developed the three layer model of value stream oriented production control. The three layers consist of the value stream, the production control and the master data management. Defining control segments stresses the idea of finding segments with equal production control methods in order to simplify production control [5].

Besides mentioned approaches, also simulation can be used for configuration of production control [5, 19]. By support of simulation, different scenarios of production control strategies can be tested cast-efficiently and easily without affecting operation.

3.3. Research deficit

Although many production control principles have already been developed, it is still difficult for companies to configure their production control in an adequate way. Different problem settings of companies show that it is not sufficient to configure production control by deterministic control rules. Many problems for example occur due to misunderstandings, choice overload or a lack of communication. Especially the socio-technical influence on the performance of production control is almost neglected in existing approaches so far. There is a lack of configuration approaches which also consider the work and decision situation of a production controller. The question is how to design the workplace of a controller so that he is able to make the right decisions.

4. APPROACH

The new approach to configure production control faces the described research deficit. The approach is based on the hypothesis that deterministic control rules are not sufficient for a proper production control. Due to the dynamic environment of a production, a balance between stable processes, control rules and adaptable processes is necessary, see Fig. 2.

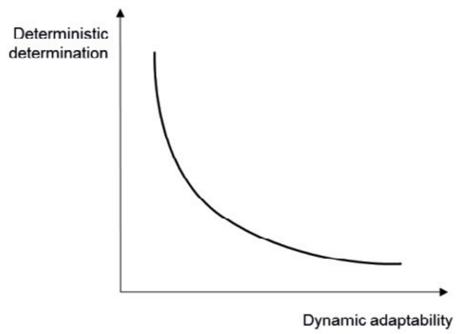

Fig. 2: Trade-off between stability and adaptability

Transferred to the focus of production control, the hypothesis is that people take the role to adapt processes and its control. Consequently, the operator is able to control complex production systems supported by existing control rules and IT. Therefore, the aim of this approach is to take such socio-technical system aspects into account. For the derivation of an approach, the socio-technical influences on production control shall be analysed first.

4.1. Socio-technical system effects in production control

Socio-technical system effects vary depending on the control task and the hierarchical position. The production controller is responsible for order creation and order release. He has to determine the right starting point and sequence of production orders. Therefore, the working effort of orders has to be compared to the capacities. Since capacity fluctuations can occur for instance due to holidays, the production controller has to discuss the capacity need with the production foreman. When an order is started in production, the production controller has to monitor the production progress. Moreover, the production controller is also responsible for the integration of priority orders into the production plan.

The production foreman's task is to ensure a smooth production process. Therefore he decides, together with production controller, which orders to produce. The production foreman makes a detailed plan for a sequence. Since the starting order sequence can change during production process due to different production paths and operating times, the production foreman should be able to optimize production performance by skilfully choose another sequence of orders.

The machine operator sometimes also changes production control for a better machine utilization. When an order has been completed on a machine, the machine operator is responsible to give feedback of the order completion to the IT-system. Furthermore, machine operators often have to control the quality of the work piece.

When considering the task of a production controller or operators which are involved into production control, socio-technical influences can be derived. It is particularly important which people communicate with each other, how often, how long and where they do so. Furthermore, the systematics how to make decisions is crucial for the quality of control decisions. For instance, in case of non structured decision processes, the experiences of a single operator determine the sort of decision. Besides personal features, the transparency of information is important. Where is information stored and does everybody who requires this information know that it exists and where it exists? Additionally, a common understanding of the production control and the logistic targets is necessary so that all people work for the same superior objective.

Summing up so far, the deterministic rules of production control have to be replenished by socio-technical system elements. We suggest a structural model which should include the right data, people with their need to communicate, to interact and to decide on topics according to a defined schedule. These socio-technical system effects are necessary to improve adaptability and to increase the viability under unpredictable and volatile boundary conditions.

4.2. Socio-technical approach for configuration of production control

Since neither the deterministic rules nor the social-technical system elements alone are able to overcome the complex challenges of production control, the new approach combines both sides, see Fig. 3. In dependence of external and internal influences, control tasks and specific production situation, a optimal working point can be found.

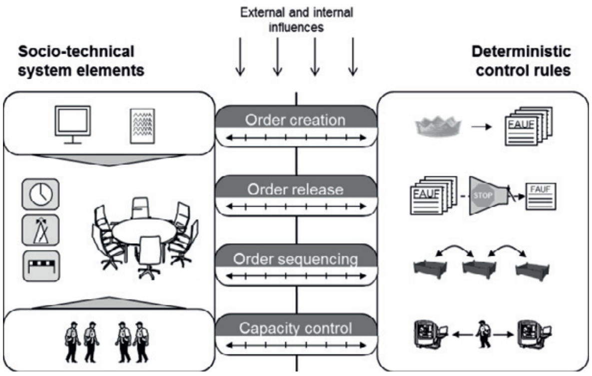

Fig. 3: Socio-technical approach for configuration of production control

The left side of Fig. 3 symbolizes the elements of the socio-technical system. For the designing of those elements, four aspects are important: people, information, time and topic. It is necessary to define those four aspects properly in order to determine a structure in which people and their skills and knowledge are in focus. Also the structure enables an increased decision and controlling quality. The right side of Fig. 3 shows the well-known production control rules. They are important as they give a basic structure to the production process. Furthermore they enable a proper production flow. Since the installed rules are rather static and not suitable for dynamic production processes, the control principles have to be complemented with socio-technical system elements. Internal and external influences decide whether it is necessary to design production control with rather deterministic rules or with more adaption feasibility by involving employees. In this context, relevant internal and external influences are for instance the product variance, quantities or lot sizes, necessity of short-term control interventions or transparency of IT systems. In the following, examples for each production control task will be described in order to explain how a proper operation point between both described sides can be defined.

Within order creation, typical tasks are defining lot sizes, fixing the delivery date and disposing the material. When the delivery date is set in an ERP system, dynamic process optimizations within the ERP system lead to changing delivery dates during the order processing. The result of this procedure is that the delivery date and therefore the prioritization of orders can change everyday. Consequently, this confuses employees. Furthermore, the generated internal turbulence by continuous prioritization changes leads to long throughput times. Therefore, production controllers have to react to changing order prioritization. Often, a negligence of the new calculated delivery dates within ERP system leads to a smoother production process and to shorter throughput times. Nevertheless, regular meetings between sales (customer contact person), production controller and production foreman are necessary to discuss urgent orders and delivery dates. Besides this example of changing delivery dates however, the control task of order creation is comparatively standardized and can properly be mapped in an IT system.

The task of order release determines the number of orders within the production system. Therefore, order release makes assumptions about WIP and throughput times of orders. Although IT representatives claim the opposite, today´s IT systems are not able to limit WIP for detailed planning. Thus, operators have to take over the task of order selection to decide which orders to release. In case of more than 50 created orders waiting to be released into production - which is not untypical for a manufacturer of individual and small series production -, operators are not able to overlook all orders properly. Hence, a support by a defined control rule or even by an IT solution is necessary. For instance, the CONWIP rule allows operators to limit the WIP easily. Combining this rule with a tool which calculates the most urgent orders, an adequate order release should be feasible.

The sequencing task determines the order prioritization. One problem which has to be considered in this context is the often underestimated frequency of urgent orders. Fearing that jobs are completed late, many urgent jobs are created. The intensity of urgent orders, however, affects the compliance of sequencing rules. Given a rate of 20% of urgent orders within production (assumption of 1500 orders in production and an average waiting queue in front of a machine of 8 orders), the probability that an urgent order is among the waiting queue in front of a machine statistically equals 80%. In such a case, there is no need for a sequencing rule because orders are only processed by urgency anyway. Just as in order creating, operators have to estimate the urgency of an order status. Several industry projects have shown that many interventions in order prioritization lead to fluctuating throughput times. To avoid this, consistently applied sequence rules help to stabilize processes. Nevertheless, a separate team regularly has to identify really urgent orders.

The last production control task, the capacity planning is perhaps one of the least standardized processes within production control. Mostly, the qualification level of operators is not mapped within the IT system which hinders a proper allocation of operators to machines. Therefore, production foremen have to decide on how to allocate their employees to their machines. Since often the machines can only proceed under guidance of operators, this allocation topic is quite important for capacity planning. Usually, the allocation of operators is done by production foremen under special consideration of bottleneck machines. In case of an operator`s illness, a substitute has to take over. Since there are almost no real rules to plan and control capacities, especially human labour, there is no alternative than to include executive personnel (e.g. production foreman or production controller) into production capacity´s planning.

5. IMPLEMENTATION WITHIN THE MANUFACTURING INDUSTRY

The introduced approach has already been implemented in several industry projects. In the following, one example of the reduction of throughput times in a single and small batch producing company shall be explained.

The company, organized as job shop manufacturing with more than 100 machines, had problems with fluctuating throughput times. An analysis of order fulfilment processes on shop floor showed that the prioritization was done manually and differently by every worker. In order to stabilize processes, a simple first-in-first-out rule was implemented. The production program and capacities were kept constant. This radical cut from totally freedom of choice towards the strict following of sequencing was necessary for stabilising processes. In a second step, operators were asked to bring in their own opinion, in order to improve processes. In several meetings, people came up with useful proposals on how to keep processes stable on the one hand, but also to handle orders with high set-up times or urgent delivery dates on the other. Using static rules combined with workers' experience and know-how, throughput times could be reduced significantly. Finally, structures were established to allow workers to bring up their own ideas but also to create a smooth production process.

6. SUMMARY

This paper introduces an new approach to improve configuration of production control. For all processes which follow mainly standardized proceedings, deterministic production control rules can be used. In case of more dynamic influences with little predictability, the consultant of operators is necessary to handle these complex systems. Due to today´s production challenges, the approach combines the best of those "two worlds". On the one hand it makes use of the predictability of deterministic control rules whose functionality has been proven in practice several times and which can be implemented quickly. On the other hand it enhances adaptability by the involvement of people in order to achieve increasing viability under volatile conditions. The purpose of this approach is to sensitize that the configuration consists of both technical and social aspects. Since given approaches have not consider the socio-technical side for configuration of production control systematically, this approach represents a new perspective of high relevance. Further research is needed for instance to quantify the socio-technical effects on production control.

Acknowledgements

The new approach of Interactive visualization in production control is being investigated by the Laboratory of Machine Tools and Production Engineering (WZL) within the publicly funded research and development project: "Cluster of Excellence - Integrative Production Technology for High Wage Countries" (German Research Foundation, DFG).

References

[1] Wiendahl H.-H., Behringer S.: Stolpersteine der Liefertermin-ermittlung und -erfüllung, in: Liefertreue im Maschinen- und Anlagenbau: Stand - Potenziale - Trends, Schuh G., Westkämper E., study results of FIR, IPA and WZL, Aachen and Stuttgart, 2006, pp.19-32.
[2] Schuh, G., Stich, V.: Produktion am Standort Deutschland. Edition 2011. Aachen: Druckservice Zillekens, 2011.
[3] Schuh, G. et al.: "High Resolution Production Management". In: AWK Aachener Werkzeugmaschinen-Kolloquium (Ed.): Wettbewerbsfaktor Produktionstechnik: Aachener Perspektiven. Aachener Werkzeugmaschinenkolloquium 2011. 1. Edition, Herzogenrath: Shaker, 2011, pp. 61–80.
[4] Münzberg, B., Nyhuis, P.: Individual Configuration of Production Control to Suit Requirements, Proceeding of World Academy of Science: Engineering and Technology (International Conference on Manufacturing and Industrial Engineering), 2009, p. 47.
[5] Schuh, G., Franzkoch, B., Potente, T., Fuchs, S.: Simulation based configuration of value stream oriented production control, Conference Proceedings POM 21st Annual Conference, POM 2010 Conference program bulletin, Vancouver, 2010. p. 144.
[6] Bullinger, H. J. et al.: Neue Organisationsformen im Unternehmen, Berlin: Springer, 2003, p. 347.
[7] Schuh, G., Potente, T., Fuchs, S., Thomas, C.: Effects of production structure and production control to logistic targets. In: Frick, J. (Ed.): Proceedings of the APMS 2011 International Conference - Advances in Production Management Systems, University of Stavanger Stavanger/ Norway, 2011.
[8] Milberg, J., Neise, P.: Organizational Design of Supply Chains, WGP, Production Engineering XIII/2, 2006, p. 181-186.
[9] Wiendahl, H.-P., Cieminski, G. v.: Stolpersteine der PPS – Symptome, Ursachen, Lösungsansätze, wt-online, 2005 (9), p. 717-725.
[10] Wiendahl, H.-H.: Stolpersteine der PPS – Ein sozio-technischer Ansatz für das industrielle Auftragsmanagement. In: Nyhuis, P.: Beiträge zu einer Theorie der Logistik, Berlin: Springer, 2008, pp. 275-304.
[11] Beck, J., Liesenkötter, M., Teucher, R.: Der Mensch im Industriebetrieb - Gestaltung von Arbeit und Technik in der modernen Organisation, Opladen: Westdt. Verlag, 1996.
[12] Gasser, R., Fischer, K., Wäfler, T.: Decision Making in Planning and Scheduling - A Field Study of Planning Behaviour in Manufacturing. In: Fransoo, J. C., Wäfler, T., Wilson, J. R., Behavioral operations in planning and scheduling, New York: Springer, 2011, pp. 13-30.
[13] Lödding, H.: Handbook of Manufacturing Control, Berlin: Springer, 2012.
[14] Goldratt, E. M.: What is this thing called Theory of Constraints and how should it be implemented? North River Press, Great Barrington Massachusetts, 1990.
[15] Hopp, W. J., Spearman, M. L.: Factory physics, 3rd Edition, New York: McGraw-Hill, 2008.
[16] Little, J. D. C.: A Proof for the Queuing Formula: L = W, Operations Research, No 9, 1981 (3), pp. 383-387.
[17] Bechte, W.: Steuerung der Durchlaufzeit durch belastungs-orientierte Auftragsfreigabe bei Werkstattfertigung, Düsseldorf: VDI, 1984.
[18] Wiendahl, H.-P., Nyhuis, P.: Fundamentals of Production Logistics, Berlin: Springer, 2009.
[19] Baumann, M., Dimitrov, T.: Simulation zur Auswahl und Parametrisierung einer Produktionssteuerung, Productivity Management, 16 (2011), p 23-25.